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MAN AND THE MICROBE

HOW COMMUNICABLE DISEASES ARE CONTROLLED

BY
C.-E. A. WINSLOW, Dr. P.H.

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MAN AND THE MICROBE

HOW COMMUNICABLE DISEASES ARE CONTROLLED

BY

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INTRODUCTION

THERE are three steps necessary before the benefits of scientific medical advance can be available to the people at large: First, there must be scientific research ending in the discovery of facts. This is usually accomplished by experimentation on animals and observation on man. Second, these discoveries must be studied in the prevention or cure of disease. This is done by the medical profession throughout the world under varying local and climatic conditions. Third, the knowledge of these facts and the methods of their application and utilization must be put into popular language and made known and available to the people.

A striking illustration of the above statements will make them clear. In the sixties and seventies of the last century Villemin demonstrated by experiments on animals (1) that tuberculosis is a contagious and therefore a preventable disease, (2) that the virus of this disease is present in the sputum and other discharges from tuberculous men and animals, (3) that the disease is transmitted from man to man and from animals to man. A few years later Koch demonstrated and isolated the living virus in the form of a bacillus and proved that it is the sole cause of the disease. These discoveries were subjected to most critical tests at the hands of medical men and it was shown that the bacillus in the sputum and other tuberculous excretions is easily destroyed and that in this way the spread of the disease might be greatly restricted. However, but little was accomplished until intelligent laymen took up the matter

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and formed the National Tuberculosis Association in 1904. Through this and other agencies the public has become well informed as to the measures necessary to restrict it. The result has been a great decrease in the number of infections and deaths from this disease.

Similar illustrations might be given with other diseases, but these will come out in the text.

Professor Winslow has rendered the public an important service in the preparation of this book. I am sure that it will be of great aid to the intelligent reader in his efforts to protect himself and those dependent upon him from infection.

VICTOR C. VAUGHAN, M.D., LL.D.

Washington, D. C., *January,* 1924.

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MAN AND THE MICROBE

CHAPTER I

PARASITES AND PARASITISM

The Pestilence that Walketh in Darkness

AMONG the manifold disorders which cripple health and efficiency and shorten human life there are some whose nature is obvious at a glance. Drowning, burning, automobile accidents, sever the vital thread with a violence which requires no explanation. The failings of old age, while their essential nature offers problems of deep subtlety to the physiologist, clearly form a part of a general law which must have become familiar even to the untutored savage. There is another group of diseases, however, whose workings are much more mysterious, the group of the plagues, pestilences, and fevers, or as we call them to-day, the communicable diseases.

We have learned so much about these disorders during the past half century that it is perhaps difficult to realize how deep was the mystery which still shrouded them when our grandfathers were young. Let us for a moment divest ourselves of this relatively recent knowledge and consider how puzzling the phenomena were which confronted the student of these problems only fifty years ago.

A man wakes up in the morning, young and strong and sound. During the day he begins to be conscious of a dull uneasiness. He feels tired for no reason.

His head aches. His throat may become sore. Gradually his discomfort increases. He grows hot and feverish. He gives up work, and goes home. He can not eat. He decides he is ill and goes to bed. He tosses through the night, more and more feverish and miserable. In another twelve hours he may be so weak that he can scarcely lift his head. In still another he may be raving in delirium.

What has happened, to strike down a man in vigorous health into a wreck of his former self in a few brief hours?

There is a second characteristic of diseases of this class, as remarkable as their sudden and mysterious onset. The disorders of old age are generally progressive. By medical and hygienic treatment their course may be checked, but it is difficult to remedy the harm already done. It is true that the fevers frequently leave behind them ineradicable injuries to vital organs. Yet these fevers themselves are essentially "self-limited" in nature. Irrespective of treatment of any kind, they run a definite course of days or weeks or in some cases of years, and at last the patient, if he has not died, recovers from the primary disease, and not only recovers but possesses against the particular malady in question a special immunity which he did not have before. Another phenomenon of a most puzzling and incomprehensible kind!

Finally, the diseases of this class are characterized by a third mysterious quality—that which has given them their name of the *communicable* diseases. When such a disorder appears in a community which has hitherto been free from it—as the influenza came to America in October, 1918—it spreads from one person to another, as fire passes from tree to tree in a forest conflagration. Is it any wonder that the ways of "the pestilence that walketh in darkness" should have awakened the awe and the wonder of mankind?

Primitive Theories of Disease

The first attempts to explain the origin of the plagues and pestilences were naturally based upon a belief in supernatural causes. Primitive man walked in a world of shadows surrounded by vague and unseen spirits of good and evil endowed with passions like his own. An epidemic was the visitation of some evil demon analogous to the onslaught of a war-like human foe, to be met by propitiating the hostile spirit or by enlisting the protection of some tribal god to combat its malign intent. Preventive medicine logically consisted in the use of charms and incantations, of amulets and sacred symbols, such as survive to the present day in the horse-chestnut carried in the pocket to ward off rheumatism, or the bags of camphor worn round the neck during the influenza outbreak in 1918.

As is the case throughout the whole realm of science, it is to the Greeks that we owe our first rational theories of the nature and origin of disease. The science which burst into a sudden blaze of glory on the rocky islands and capes of the Ægean Sea was often crude and faulty; but it was science. It involved the assumption of natural physical causes for natural physical phenomena. Even when the assumptions were erroneous they could be tested and proved, elaborated or replaced by better ones. They gave us a definite basis for advance, while the recourse to a theory of irresponsible supernatural forces left no door open for the progressive working of the human intellect.

In the case of the plagues and pestilences the Greek theory was particularly faulty. As enunciated by the great Hippocrates it attributed these disorders to the influence of miasms, subtle emanations in the atmosphere, scarcely less mysterious (and scarcely more actual) than the demons of an earlier age. It

was believed that the plague of Athens was checked by lighting fires in the streets to purify the atmosphere from its deadly miasms.

Yet it was in reality a great step forward to conceive of an epidemic as due to miasms rather than spirits. It opened the way for speculation; and even among the Greeks there were those who perceived the real nature of these diseases more clearly than the official medical leaders of the time. The contagious nature of the plague was quite definitely described by Thucydides, and throughout the later periods of classic medicine this conception of contagion persisted in parallel with the Hippocratic doctrine of miasms. With the spread of leprosy in the Middle Ages, beginning about 550 A. D., the practise of isolation and quarantine laid down in the book of Leviticus became widely current as a method of control, culminating in the famous leprosy decretals of the third Lateran Council. So effective were the measures taken by the princes and bishops of medieval Europe for the isolation of lepers that this disease was practically stamped out by the end of the sixteenth century, giving us the first example on a large scale of the power of man in controlling the plagues and pestilences to which he had hitherto been a helpless victim.

The campaign against leprosy had been favored by the fortunate circumstance that this particular disease is only slightly contagious. In dealing with plague and typhus fever, the science of medieval medicine proved ineffective, as was necessarily the case when a real knowledge of the nature of underlying factors was almost wholly lacking. Even the theory of contagion was applied only to a few of those disorders which are really due to its operation. Typhoid fever and cholera were still attributed to the working of atmospheric miasms and held not to

be contagious. As late as 1865 the leading medical authorities of Great Britain taught that the bodily discharges of a cholera patient were not dangerous until they had become decomposed and generated the miasms of disease. Isolation was an instinctive precaution which even when blindly used was helpful in certain instances. So far as a really adequate theory was concerned, such as could make possible the general control of communicable disease, the physician of 1860 was almost as ill-equipped as his predecessor in the time of Hippocrates.

Pasteur

Meanwhile, however, in the dingy laboratories of the Ecole Normale at Paris an obscure young Frenchman was eagerly at work on a series of investigations which were to open a new world of thought and to lift from mankind a large share of the age-long burden of preventable disease.

Louis Pasteur, the son of a humble village tanner, was at this time (about 1860) engaged in the study of the complex problems of fermentation. The curious phenomena which occur when sugar solutions ferment, or milk sours, or organic substances putrefy, were generally attributed to the direct action of the air. This vague explanation did not satisfy Pasteur. He studied fermenting fluids by chemical analysis and by the use of the microscope and became convinced that the minute rod-shaped or spherical or oval living things which swarmed in such fluids were not present by accident but were intimately connected with the production of the changes which were going on. By a brilliant series of rigorously controlled experiments he succeeded in demonstrating beyond the shadow of a doubt that these changes in organic substances were indeed caused by microbes, and that for each particular kind of fermentation or putrefaction

a particular kind of microbe was responsible. His first great contribution was to establish the germ theory of fermentation.

In 1865 the silk industry, which furnished the major means of support for certain departments in the south of France, was threatened with extinction by the spread of a disease among the caterpillars which produce the golden fibers. Pasteur was called upon for help. He found in the bodies of the sick worms minute corpuscles which looked like the microbes he had identified in fermenting wine and beer; and by 1870 he had definitely proved that the disease of the silkworms was due to these microbes and that it could be controlled by breeding worms only from stock free from microbes and then protecting them from subsequent infection.

The silkworm industry was saved, but much more than this had been accomplished. A first step had been taken in the demonstration of the germ theory of disease. By 1877 the same proof was furnished in regard to a disease called anthrax or splenic fever affecting cattle and men, Pasteur himself and Robert Koch in Germany completing the demonstration independently and by somewhat different means. In 1882 came the discovery of the germ of tuberculosis, in 1883 that of cholera, while in 1884 the microbes causing typhoid fever and diphtheria were unmasked. From that time to this, the triumphs of bacteriology have gone steadily forward to the recent brilliant studies conducted at the Rockefeller Institute in New York on yellow fever and influenza. Methods of research have been broadened and altered in detail, but their general lines were laid down by the founder of bacteriology sixty years ago. Above all, the spirit of Pasteur, the caution, the modesty, the patience, the rigorous insistence on the truth, the whole truth and nothing but the truth, which characterized his

work, have proved an inestimable inspiration to all later investigators in this field.

With the key furnished by Pasteur it was relatively easy to unlock many of the mysteries which had shrouded the communicable diseases; and through the applications by Joseph Lister of the germ theory to antiseptic surgery the operating room and the maternity ward of the hospital were robbed of their earlier terrors. It is probably safe to say that no one man who ever lived has accomplished more than Louis Pasteur for the practical well-being of the human race and of the races of animals which mankind has domesticated for its uses and its pleasures.

The Ubiquitous Microbe

We realize to-day that the invisible microbes which are all about us, in air and earth and water, as well as on the surfaces of our bodies, play an important part, sometimes for good and sometimes for ill, in the affairs of our daily lives. It will be well, therefore, to give a brief consideration to some of their characteristics.

There are various different kinds of microbes as there are different kinds of living things of larger size. Some of the microbes are animals, like the hookworm which causes so much disease and suffering in our own southern States and in most tropical countries. Some are smaller and simpler in structure but still clearly allied to the animal kingdom, like the germ of malaria. Some are so minute that we have no real knowledge of their nature. We call them "filterable viruses" because they are so tiny that they will pass through the pores of a fine porcelain filter which holds back most of the microscopic living things with which we are more familiar. The most abundant, and on the whole, the most important microbes, however, belong to a group called the bac-

teria whose characteristics we may profitably discuss in more detail.

The bacteria are minute plants related to such low forms of life as the molds and yeasts, microbes with whose operation every housewife is familiar. They have almost no structure, no leaves and stems and roots like the higher plants, but are simple single cells analogous to the elementary structures out of which, as the microscope tells us, the leaves and stems and roots of the higher plants are built up. Each of these bacterial cells has a wall on the outside and a mass of living stuff or protoplasm within. They are shaped like sticks (the word *bacterium* in Latin means a stick or rod), or balls or spiral threads, and are so small that 400,000,000 could be packed into a grain of granulated sugar. Some of them have wavy processes or flagella which they use like fins to swim about in liquids. Some of them can pass into a specially resistant resting stage called a spore, with a heavy wall, in which condition they are very resistant to heat or the action of disinfectants. This is almost all that can be seen in regard to their visible structure even with the most powerful microscope.

If the bacteria are small and simple in structure they nevertheless possess powers of growth and multiplication which are astounding. They normally reproduce by the simple process of growing larger and then splitting in half, so that two bacteria are present where there was only one before; and under the most favorable conditions this reproduction may take place as often as once in twenty minutes. The application of simple arithmetic will show that a single germ may at this rate produce a billion descendants in ten hours.

Moreover, the bacteria in the course of their reproduction produce profound and far-reaching changes in the medium in which they are growing. They

absorb food through their cell walls from the adjacent liquid and in order to secure this food they break down the materials in the liquid by discharging chemical substances called enzymes which possess the power of decomposing the sugar or the protein or some other organic compound which will yield up what they need. It is in this way that fermentation, souring, decay, and all sorts of decompositions of organic substances are normally brought about.

There are a few bacteria floating in the air of every room. There are some in every glass of water which we drink and on nearly every mouthful of food which we consume. There are many thousands in every tiny speck of dust or dirt. There are millions of them in the mouth, in the intestines, and on the skin of every part of the body. Fortunately the vast majority are quite harmless and many of them are even of direct service and benefit to man. The effect upon our lives of microbic growth depends on the kind of substance in which the particular type of microbe grows and on the kind of chemical change which it produces in that substance. The disease bacteria constitute a very small minority able to grow in the tissues of the human body, a power which most of the group as a whole do not possess. Of the majority, adapted for development only in lifeless organic substances, those which spoil milk or meat which we want to keep sweet are harmful to us. But those which produce the particular change which transforms milk into buttermilk are beneficial, if buttermilk is what we want. In the flavoring of butter, in the manufacture of vinegar, in the retting of flax, in tanning, and in various other industrial processes, bacteria are used with great advantage. Above all in the elimination of the dead bodies of plants and animals in the woods and fields and in various chemical changes connected with the mainte-

nance of the fertility of the soil, the bacteria play a part of inestimable importance in the cycle of forces which make possible life upon our earth.

The Phenomena of Parasitism

The really dangerous kinds of microbes are those which in the course of evolution have acquired the habit of living in the human body and at its expense. We call the animals and plants which live in this way parasites, from a Greek word applied to the hanger-on at a great man's house, and it is perhaps wholesome to remember that the habit of parasitical living is not limited to the microbic world. In many of the major groups of animals between man and the microbe there are species which have adopted the habit of parasitism, particularly among the insects and the worms. Turning to the plant kingdom the molds and fungi are by no means the only representatives of this habit. The mistletoe owes its sacred character to the fact that it keeps green in winter, but its brilliant foliage is supported by vital energy drawn from the tissues of the oak upon which it lives as a parasite.

There is one interesting thing to notice about the parasite in all his manifestations. He has gained the power of living in an unusual and abnormal environment,—the body of his host, as biologists, with a certain unconscious humor, call the victim of a parasite; but he has lost something in exchange. The human parasite in the Greek drama, if he had been living for a long time in this unnatural way, had probably forgotten how to earn his living in the ordinary hurly-burly of every-day life. Just so the parasitic microbe has lost in large measure the power to live and grow in water or earth or decomposing matter or in any of the other environments in which his harmless relatives can thrive.

This is a point of the first importance in connection with the spread and the control of communicable disease. A parasitic microbe capable of growing in the human body can thrive only in the human body (or in certain instances in the body of some other animal). It may and often does survive for a time in water or soil or filth, but only for a time. Disease bacteria when outside the human body are almost always dying out, and as a rule are dying out with great rapidity. There are exceptions to this, as to all rules. In milk, for example, certain disease germs find a culture medium in which they may grow and increase. In water, in earth, in dust and air, however, the parasitic microbes quickly perish.

Let us take water as an example: Sir Alexander Houston, the bacteriologist of the London Water Board, put some typhoid germs into a bottle of water. There were 470,000 of them in one cubic centimeter (a small thimbleful) of water at the beginning of the experiment. Then he merely let the bottle of water stand in his laboratory. At the end of one week there were 480 bacteria per cubic centimeter; at the end of two weeks, there were 31; at the end of three weeks 5; and at the end of four weeks all were dead.

The discovery that disease germs perish so rapidly when removed from the rich warm fluids of the body has made it clear that we need not really be afraid of many things which our fathers feared in the early days of the germ theory of diseases. Fomites (clothing, books, toys, or other objects which have been used by a sick person) will be dangerous if they have recently been handled, but the danger will not persist for very long. We can draw no sharp line or say that at 4.20 p. m. some object is dangerous and at 4.30 p. m., safe. If a person with a cold coughs in his hand and then with that hand passes

me an apple, I shall be likely to contract that cold. If he puts the apple down and leaves the room and I come in and pick it up five minutes afterward, the danger is much the same. If the apple stays over night before I touch it, the risk is less. If it stands for a week, there is very little chance that I shall become infected. As to the tales of toys put away for years and then transmitting disease, we take no stock in them at all.

For the same reasons it seems probable that dust in the past has been over-rated as an agent in the transmission of disease. Some germs may survive drying and it is quite possible to find germs of tuberculosis in the dust of a room which has been occupied by a careless patient. The number of such germs is very small, however, as compared with the vast multitude originally present in the sputum; and the reason why the proper care of sputum is so important is much less because of the danger that it may dry up and blow about in the form of dust than because it may be transferred, while the germs are fresh and virulent, by shoes, skirts, fingers, flies, or in some other ways.

The original source of disease germs, then, is the human body (or the body of one of the higher animals); and the transmission of disease is ordinarily accomplished only by the rather prompt transfer of bodily discharges from one human being to another.

The Carrier

Bacteriological science has thus relieved us of much of the fear which was once entertained in regard to dust, fomites, decaying filth, or in general the environmental factors once held to be primary factors in the causation of disease. On the other hand it has revealed new and unsuspected possibilities of

danger among our families and friends and associates by the discovery of the part played by the human carrier.

A "carrier" is a person who is himself well, but is cultivating in nose or throat or intestines or gall bladder the germs of some disease, against which he is immune but which may be transmitted by his bodily discharges to any one who lacks the special resistance which he himself has acquired. The convalescent from typhoid fever for example in a certain proportion of cases (3 to 4 per cent.) continues to excrete typhoid bacilli after recovery is complete; and it has been estimated in the past that three or four persons out of every thousand in the general population might be typhoid carriers (altho the number is probably smaller to-day). Diphtheria bacilli are even more prevalent in the throats of normal persons, two or three out of every hundred showing organisms of this type, often not virulent but sometimes actively so. Cerebrospinal meningitis and epidemic poliomyelitis are spread largely and perhaps chiefly by carriers, and the carrier plays a predominant part in the transmission of pneumonia.

The most famous (or infamous) carrier in the history of public health is the cook known as "Typhoid Mary," who between 1902 and 1907 while employed in six different families was the cause of typhoid cases in every family, infecting 26 persons in all. In 1907 she was taken to a hospital and found to be a chronic typhoid carrier. She was released and was lost to sight for a time; but in 1915 25 cases of typhoid occurred in the Sloan Hospital of New York and Mary was found to have been employed there. Many other cases were probably, tho not certainly, traced to her activities, and it is even possible that she was the cause of the water-borne outbreak of 1,300 cases at Ithaca, N. Y.,

in 1903. Another carrier whose story is even more surprizing was a farmer who had typhoid fever in Wisconsin in 1864. He recovered and moved to Camden, N. Y., where he set up in the milk business. In 1878 his daughter had typhoid, in 1886 his son-in-law, in 1893 another daughter, in 1897 another, in 1903 and 1909 two hired men. Meanwhile Camden became notorious for its generally high typhoid rate, three-quarters of the cases being among the users of this farmer's milk. Finally, in 1900, some of this milk was sent to New York and caused an epidemic of 380 cases, when the New York authorities investigated, found the man to be a typhoid carrier and cleared up the whole story.

It is the carrier on the one hand and the case of disease in the early and unrecognized stage on the other which are responsible for the numerous infections which arise without previous contact with an obvious case. Such infections were wholly mysterious before the discovery of the carrier; and it was such puzzling cases which were explained by far-fetched assumptions as to miasms or fomites. It is contact with an incipient case or a carrier which usually spreads diphtheria and scarlet fever—not the air from a broken drain, or the book which was handled by a sick person several weeks ago.

The Control of Communicable Disease

It is clear, then, that the original source of disease germs is the human case or carrier; that these germs generally leave the body in its discharges; that they die out rather rapidly when removed from their normal habitat which is the body itself; and that the transmission of disease must therefore be effected by the rather prompt transfer of body discharges from one human being to another. In formulating a program for the control of the communicable dis-

eases it is first of all essential to consider in what ways such transfer of infected discharges is most likely to be accomplished. It will then be possible to devise the best means for breaking the chain of infection.

The agencies by which body discharges may be passed from one person to another are commonly called the "vehicles" of disease. The atmosphere, to which Hippocrates looked for the origin of epidemics, can not be a vehicle of disease, except in so far as coughing or sneezing may produce a fine spray in the immediate neighborhood of an infected person or by the transfer of disease germs through the atmosphere by flying insects. The microbes themselves have no wings and even the mouth spray thrown out in coughing is made up of solid particles which fall to the ground rather rapidly. Dust is not an important or a common vehicle of disease, since in the process of drying the vast majority of disease-producing microbes will have perished; and for the same reason fomites are not particularly dangerous unless they have been recently soiled with the discharge from a sick person or a carrier. In many modern hospitals contagious diseases of various kinds are cared for in the same ward with only screens between the beds to prevent direct infection by mouth spray, and so long as care is taken to prevent the spread of disease germs by the fingers of attendants this system can be used without fear of cross-infection.

The first and most important way in which the spread of infection does take place is by contact—the more or less direct transfer of discharges by mouth spray, by the hands, and by objects which have been recently handled. A second class of vehicles of infection includes certain articles of food and drink—water, and milk, for example—which are

exposed to pollution and are then consumed within a short space of time without cooking. A third mode in which disease germs are spread is by means of certain insects, as the fly and the mosquito, which carry the microbes on, or in, their bodies from one person to another. These three modes of infection, by contact, by food and drink, and by insects, account for the vast majority of cases of communicable disease. They have been described in alliterative form as the "three F's of sanitation, fingers, food, and flies," "fingers" standing for all forms of more or less direct contact, "food" for food and drink of various sorts, and "flies" for the many insect vehicles of disease. The methods by which each of these three main modes of transmitting disease may be controlled will be discussed in detail in succeeding chapters.

CHAPTER II

MUNICIPAL SANITATION

The Care of Body Discharges

THE communicable diseases belong to two main groups, those in which the germs are present in the discharges from the nose and throat, such as the common cold, pneumonia, diphtheria, measles, and the like, and those in which the germs are spread by the discharges from the intestines and the kidneys, of which typhoid fever and dysentery and cholera are examples. The nose-and-throat diseases are for the most part spread by contact, and the control of these contact-borne infections will be considered more fully later on.

The germs of the intestinal diseases, on the other hand, leave the body in the discharges from the bowels and bladder, and these discharges are frequently transmitted by water or milk or other vehicles over a large area and to great numbers of people. In the southern part of the United States, and in tropical and semitropical countries throughout the world, this problem is of peculiar importance, since in warm climates typhoid fever, dysentery, and various diseases due to parasitic worms, particularly hookworm disease, are all commonly disseminated through the improper disposal of human excreta. Few of us who live in the sewered cities of the North fully realize the importance of this problem; but the International Health Board of the Rockefeller Foundation estimates that out of a total of some seventeen hundred million people inhabiting the globe,

over nine hundred million live in countries where hookworm infection is a serious menace to health and working efficiency.

Hookworm disease is an example of a communicable disease in which the process of infection is so clearly understood that it gives us an excellent picture of what goes on in the case of other maladies whose history has been less completely studied. The parasites in this case are tiny worms about one-third of an inch in length which attach themselves to the walls of the intestines and suck the blood of their victim, sapping his energy and lowering his vitality in proportion to their numbers. They reproduce and lay eggs which pass out with the intestinal discharges. The young worms which hatch from these eggs are spread about in the soil by casual disposal of excreta and penetrate into the bodies of new human hosts in a very curious fashion. In the warmer countries the majority of the agricultural population go barefoot and these worms bore their way through the skin of the foot and after thus entering the body find their way to the intestines where they attach themselves and continue their normal parasitic existence.

There are two general methods which may be used in the control of hookworm disease. By the use of certain specific drugs it is possible to destroy the worms in the intestine and thus cure the individual patient. The fundamental prevention of this disease obviously depends, however, on the provision of proper facilities for the care of human excreta so as to avoid the pollution of soil and the consequent infection of new victims. This may be accomplished by the construction of tight outdoor closets, screened to exclude flies, and with provision for the care of the excreta themselves either in pits or in tight removable receptacles; or best of all, where possible,

by the introduction of a system of water closets and sewers.

In demonstrations carried out in 43 different States and countries the International Health Board has shown that hookworm disease may be controlled with striking success by the application of such methods. Thus in Richmond County, Virginia, where this work was first begun, the proportion of school children infected with hookworms, which reached the enormous figures of 83 per cent. in 1910, was reduced to 35 per cent. in 1911 and to slightly over 2 per cent. in 1921. A parallel reduction in other intestinal diseases has followed these improvements in sanitation. Thus in Troup County, Georgia, between 1917 and 1921 the cases of dysentery were reduced from 486 to 29 and the cases of typhoid fever from 177 to 15.

The Disposal of Sewage

The provision of a system of sewers solves the problem of waste disposal for the individual household in the most satisfactory manner possible. It leads, however, to the creation of a new problem of municipal sanitation—that of the treatment of the sewage itself—for somewhere at the end of the sewerage system the accumulated wastes from all the dwellings must somehow be disposed of.

The sewage of an average American city will amount to over 100 gallons a day for every person in the population. What this means may best be illustrated by saying that if the daily sewage discharge from New York City were collected in the bed of a river 100 feet wide and 10 feet deep it would completely fill it for a distance of 13 miles in one day! It is true that this river of sewage is mostly water; but the solid matter which it carries with it, tho less

than one one-thousandth of the total, would, in the case of New York City, be equal to 600 tons a day.

The damage done by city sewage which is not properly disposed of is of two distinct kinds. In the first place the disease bacteria which the sewage from any large community is sure to carry, may pollute water supplies or may cause disease among those who bathe in the polluted waters or consume shellfish taken from them. In the second place the decomposition of the organic material in the sewage may produce offensive conditions along the course of the river or harbor into which it is discharged.

The first of these problems which concerns the danger to health is often solved in some other way than by the purification of the sewage. It may often be more economical and more effective to purify the water which is taken out of a stream for drinking rather than to attempt to secure a complete purification of all the sewage which may enter it. Shellfish from a polluted area can be made safe by appropriate treatment, and it may prove a better policy to abandon a given bathing beach rather than to spend money on an elaborate system of sewage treatment. In one way or another, however, such menaces to health must always be controlled.

In any case the sewage of a city should be so disposed of that no nuisance shall be created. Sometimes no special treatment may be necessary. Where a small volume of sewage is discharged into a large stream or into the ocean, the intestinal bacteria may die out and the organic matter be disposed of by natural processes without danger of offense. As the amount of sewage becomes greater in relation to the volume of diluting water it becomes necessary to reduce the burden of polluting material. We can remove the larger suspended solids in the sewage by passing it through screens, or effect a more com-

plete reduction in suspended matter by the use of large tanks in which the finer solids settle out. The "septic tank" and the "Imhoff tank" are settling basins of this kind in which the solids which accumulate on the bottom are digested and reduced in amount by the action of putrefactive bacteria. Finally, if a higher degree of purification is necessary, the organic material in the sewage may be oxidized and turned into a harmless and inoffensive mineral form (nitrates) by the action of nitrifying bacteria. This sort of purification takes place in nature whenever manure is ploughed into the soil or when the untidy housewife throws kitchen slops out from the back door. On a large scale we can make it more effective by disposing of sewage on special beds of sand or broken stone or in aeration tanks. All these devices involve the cultivation in the sand beds, or on the stone filters, or in the aeration tanks, of special types of bacteria which, in the presence of sufficient oxygen, oxidize the organic matter of the sewage into nitrates. In the case of the sand filter the sewage is applied in intermittent doses, the air being drawn in after each application. In the stone filters, called trickling beds, the sewage is discharged from spray nozzles up into the air, and then allowed to trickle downward over the stones which are covered with bacterial films. In the aeration tanks air is blown directly in through porous plates at the bottom and sewage, oxygen, and nitrifying bacteria are thus intimately mixed.

By a proper combination of these various devices it is possible to secure any result which we desire in the purification of sewage. There is one case of a village on the shores of the water supply of a large city whose sewage is first settled, then passed through two successive stone beds, settled again, passed through a sand filter and then disinfected

with chlorin, producing an effluent purer and better than the water supply into which it is discharged. Such elaborate treatment is, of course, very rarely needed; and in a given case the aim should be to protect the public health and secure freedom from nuisance at the minimum possible cost in view of all local conditions, remembering the old maxim that "an engineer is a man who can do for one dollar what any fool can do for two."

The Problem of Water-borne Disease

It is natural to pass from a consideration of the problem of sewage disposal to that of water supply, since in the past the mingling of sewage with drinking water has so often been attended with disastrous results.

Our water supply comes originally from the rain-drop; and the water which condenses into a rain-drop has previously been distilled in the form of purest vapor from the surface of lake, stream, or ocean, or from the leaves of trees or other evaporating surfaces. As the drop forms and as it passes downward through the air it takes up a certain amount of foreign matter in the form of dust or gases, but such foreign materials are small in amount and of no sanitary significance. For practical purposes the rain water is pure when it reaches the surface of the earth. Here, however, its contamination promptly begins. As the rain washes the roofs of buildings, the streets of cities, the soil of barnyards and agricultural land it takes up large quantities of material in solution and suspension, including vast numbers of bacteria of all sorts; and if human excreta are anywhere exposed these bacteria will include numerous representatives of the intestinal flora and often some of the microbes capable of producing typhoid fever or other intestinal disease.

The surface wash thus produced by a rain-storm then divides itself into two portions. A part flows off by way of the brooks and rivers and lakes, continuing to form a portion of the surface waters of the globe. The rest trickles downward through the soil and joins the great reservoirs of what we call the ground waters, slowly passing through the soil toward river, lake, or ocean with which they ultimately mingle by subterranean routes.

As the surface waters pass into larger and more sluggish streams and lakes they gradually become purified from their original pollution by sedimentation, oxidation, and the dying out of the intestinal bacteria, and the ground waters are purified in even greater degree by the filtering action of the soil. In too many instances, however, new pollution enters by sewers discharged into the surface waters or reaching the ground waters through cracks and fissures in the soil; and the use of such waters, or of those exposed to recent washings from the surface of polluted soil, is fraught with the gravest dangers to life and health.

The first striking example of water-borne disease which occurred in the United States was at Plymouth, Pennsylvania, in 1885. The water supply of the city was derived from four small reservoirs, near one of which were a few scattered houses. A man living in one of these houses visited Philadelphia and contracted typhoid fever there, returning home in January. His excreta were thrown out on the frozen ground sloping down toward the water supply, and when the thaw came in March the polluting material was washed in, sufficient to cause 1,104 cases of typhoid fever in Plymouth out of a total population of 8,000. In 1890–91, excreta discharged into a branch of the Merrimac River caused 550 cases of

typhoid fever in Lowell, Massachusetts, which used the river water for drinking, and the sewage of Lowell was then carried on to Lawrence, nine miles below, producing over 200 cases there. Excreta from a single case of typhoid fever washed into a reservoir caused 514 cases of typhoid in New Haven, Connecticut, in 1901; and the story of such instances could be repeated almost without limit.

It is such instances as these which have at last taught the folly of using for drinking the water from any source not definitely proved to be free from pollution. In the case of surface water, experience has shown that no surface supply is absolutely safe unless effective safeguards have been supplied in the way of some purification process; and in the case of ground waters where we can not detect the presence of possible pollution by direct inspection we must rely on bacteriological analyses to determine whether there is liability of danger.

The Purification of Water Supplies

Fortunately we now have at our disposal simple and efficient and economical means of treating polluted water so as to make it safe for drinking; and, as a result of the application of such treatment, water-borne disease has in civilized countries become almost a thing of the past.

The first method of purification which can be utilized is storage. We have already pointed out that if water is held for a considerable period the intestinal bacteria present die out with considerable rapidity, so that after a lapse of several weeks even a highly polluted water will be rendered harmless. In supplies drawn from lakes this purifying agency always enters to a more or less considerable extent; and when any large city derives its water supply from a

flowing stream, an artificial storage reservoir is generally introduced to equalize the available flow. The efficiency of purification by storage can not, however, be estimated by the capacity of a reservoir alone. Experience has taught us that local currents due to wind action or some other condition may carry fresh pollution for a long distance in a short period of time. This method of purification must therefore be watched with the greatest care and controlled by constant bacteriological examinations before we can place reliance upon its efficiency.

A second and more trustworthy method of treating polluted water is known as slow sand filtration and consists in passing the water slowly through a bed of suitable sand from four to six feet deep. Such a sand bed acts as a filter, the bacteria present in the water clinging to the sand grains and to the fine material and the bacterial growth which gathers at the surface of the bed, so that the effluent which flows off at the bottom will be as safe as a good spring water. Even such polluted waters as those of the Merrimac and the Hudson Rivers may in this way be made quite safe for use.

The slow sand filter works admirably with the clear river waters of New England. In the Middle West, however, the rivers often come from regions where the soil is largely clay and such waters carry a fine turbidity which interferes very seriously with the process. For such waters we have a third method of purification which is called rapid mechanical filtration. In this mode of treatment we again use a sand filter but we reinforce the filtering action of the sand by adding a chemical, such as sulfate of alumina, which forms a heavy precipitate on the surface of the sand, and then pass the water through at a much more rapid rate. For turbid waters this

is the most efficient and economical method at our disposal.

Finally, water may be purified by chemical disinfection, the process generally used consisting in the addition either of bleaching powder or of chlorin gas. Chlorin is a powerful oxidizing agent and destroys the vast majority of the bacteria present in a very few moments without producing any appreciable change in the final composition of the water. The chief limitation to the use of this process lies in the fact that in order to be effective the amount of chlorin added must be nicely proportioned to the organic matter present in the water. If the organic content of the water increases suddenly, as is the case with river waters after a rain, the chlorin will be used up by the organic matter before it can kill the bacteria. The ideal field for chlorin treatment is to put the finishing touches on a water which has already been fairly well purified by storage or filtration. In combination with one or the other of these processes it is used by a large majority of cities in the United States.

The advantages of a safe water supply are so obvious that it is quite inexcusable for any community to take risks with a supply that is not fully protected by one of the methods discussed above. At Lawrence, Massachusetts, for example, the cost of purifying the city water amounted to about sixty cents per capita yearly. It was conservatively estimated that the reduction in typhoid fever effected by this filter involved an economic saving equivalent to over ten dollars per capita yearly. The introduction of filtration and disinfection processes has been the chief, but by no means the only, factor in reducing the typhoid fever death rate of the United States Registration Area from 36 per 100,000 persons in 1890 to less than 8 per 100,000 in 1920.

Milk Supply and Disease

Next to water, milk has perhaps been the one article of food most commonly associated with the spread of communicable disease. If one considers for a moment the conditions surrounding the production of milk it will be obvious that there are many possibilities of danger, in some respects even more than in the case of water supply. Milk comes, not from the clouds, but from the body of an animal which may or may not be diseased. It is collected in stables which are rarely as clean as the sandy shores of a well-protected reservoir. Instead of being transported in a system of closed pipes it is exposed at a dozen points on the cityward way to contact with human beings who may be carriers or incipient cases of disease. Above all, however, we can have no reliance here upon the purifying agency of storage, for milk is one of the few media in which disease germs may actually increase and multiply during transit.

Milk may produce disease in three different ways. In the first place it may transmit specific bacteria from the infected cow to man, particularly in the case of tuberculosis—and a considerable proportion of tuberculosis in young children is beyond question caused in this way. In the second place milk may become infected by human contact with the germs of various diseases, such as septic sore throat, typhoid fever, diphtheria, and scarlet fever, hundreds of epidemics having been traced to this source. Finally, there is the closest connection between cow's milk of low quality and the summer diarrheas of children, and it appears probable that these summer diarrheas are caused not necessarily by specific infection but by the development in the milk of miscellaneous putrefactive and fermentative bacteria.

The danger of milk-borne tuberculosis can be

avoided by the testing of cattle with tuberculin and the elimination from dairy herds of all animals which show a reactance to this test. So far as the decomposition of milk is concerned much may be accomplished by dairy inspection, the use of clean utensils, and particularly the careful cooling of milk in transit to avoid undue multiplication of bacteria. It is possible by a combination of these methods to produce a small amount of milk of high quality and high cost which will be clean and sweet and free from the germs of tuberculosis. Even such a product, which we call certified or selected milk, can never, however, be quite free from the danger of human infection since there is always the possibility that an unsuspected carrier may cough over a pail or touch the neck of a can; and a single such contact may produce deadly results.

Fortunately we have here, as in the case of water supply, a method of purification which will render milk really safe as well as clean and which can be applied at so low a cost as to be used with success in making the whole milk supply of a city fit for human consumption from a sanitary standpoint. This method is called pasteurization, after Louis Pasteur who first used it for the preservation of organic fluids, and it consists in the heating of the milk to a temperature of 140° to 145° Fahrenheit and holding it at that temperature for 20 to 30 minutes. This process destroys the vast majority of bacteria present in milk, including all disease germs and, if properly applied, it in no way alters the taste or the digestibility or the food value of the milk, except for the partial destruction of one particular vitamin (which protects against the disease, scurvy). Even raw milk does not supply this special vitamin in reliable quantity, so that infants fed on cow's milk, whether raw or pasteurized, should be given an anti-

scorbutic such as orange or tomato juice. It can not be too strongly emphasized that no raw milk is ever a wholly safe source of supply for children. It should be, and is, the effort of all active health authorities to secure the effective pasteurization of all milk except the small amount of milk of Certified or Grade A quality; and even the latter can profitably be pasteurized in the home before it is used for infant feeding.

Sanitary Problems of Food Supply

Water and milk supplies have enjoyed a sinister preeminence as factors in the spread of disease upon a wholesale scale, on account of their liability to pollution and the fact that they have so generally been consumed without the salutary disinfecting action involved in most processes of cookery. However, epidemics have also been traced to various other raw foods, celery, lettuce, water cress, and, particularly, oysters and other shellfish. With increasing care in the supervision of the grounds from which oysters are taken and with the practical elimination of the practise of "floating" or "fattening" oysters by placing them in brackish water (which causes them to swell up and look plumper), disease due to this cause has become relatively rare. Furthermore, it has been shown that even oysters taken from somewhat polluted sources may be rendered safe by storing them for a short time in chlorinated sea water and this process is in actual use at one or two places along the Atlantic seaboard.

Either cooked or uncooked foods may of course be infected by the "carrier in the kitchen," and numerous outbreaks of typhoid fever, paratyphoid fever, and "food poisoning" have been caused in this way. If the infective material be thoroughly mixed with the food, the bacteria inside may even survive the ordi-

nary processes of cookery, as in the famous epidemic of typhoid fever at Hanford, California, where 93 people who attended a church supper were infected by a dish of Spanish spaghetti prepared by a typhoid carrier. In certain instances food poisoning may be caused by bacteria of the paratyphoid group present in the meat from diseased animals, and very recently the bacteriologists of the New York City Department of Health traced an epidemic to the contamination of cream puffs by mouse excreta. It will usually be found on close study that such outbreaks are due to specific infection with bacteria of the typhoid-paratyphoid group from human or animal sources; and the term "ptomaine poisoning" implying that decay is the principal factor is a misnomer. Decay in itself is by no means necessarily harmful if specific disease-producing organisms be absent, as is shown by the fact that certain cheeses are habitually consumed in a state of decomposition, and by the preference of epicures for game that is a trifle "high." Protection against such diseases must be sought by inspection of animals before and after slaughter, by cleanliness in the preparation of foods, and by the exclusion, so far as possible, of carriers from the business of food-handling.

There is one other type of food poisoning of a different nature which deserves special mention—the disease known as botulism, which attracted so much attention after the war in connection with outbreaks traced to the consumption of ripe olives. The germ of this disease is rather widely distributed in soil and on fruits and vegetables in certain regions, and in foods which have been preserved by faulty methods it develops and produces a very powerful toxin. Protection against this disease can be easily insured by care in the processes of food preservation. As in the case of the paratyphoid food poisonings,

there is no necessary and universal relation between obvious decomposition and danger to health; but foods in which the bacillus of botulism has multiplied have generally been distinctly "off-color" in odor or taste. It is therefore a good rule to avoid any food that displays any such abnormalities.

CHAPTER III

INSECTS AND DISEASE

The Filthy Fly

WE may pass next to the second important mode of spreading of disease—through the medium of insects. The relation of insects to disease may be of diverse sorts. In some instances the germ of a particular disease is transmitted by a particular type of insect and in no other way. In other instances the relation between the insect and the disease may be merely an occasional and accidental one.

The part played by the fly in the dissemination of typhoid fever is of the second type. Typhoid fever is spread by water, by milk, by foods, by direct contact, and in various other ways; but if conditions are such that flies may gain access, on the one hand, to human excrement and, on the other, to food, they may and do play an important part in its dissemination. During the Spanish War when one in five of our volunteer soldiers suffered from typhoid fever the fly was the chief agent at fault. Dysentery and diarrhea may also be transmitted in a similar fashion, and even in sewered cities like New York flies play a definite rôle in the spread of infant diarrhea.

One of the most important steps in the prevention of fly-borne disease is the proper disposal of human excreta, as discussed in a preceding chapter. We may cite here the experience of Jacksonville, Florida, as an illustration of the importance of such precautions. A campaign for the rendering fly-proof of outside closets throughout this city reduced the

typhoid death rate of the city from 106 to 26 per 100,000 population.

The most effective means of dealing with insect-borne disease is always to be found in controlling the breeding of the insect itself; and for this purpose we must know something of its habits. The ordinary house-fly—better called the filthy fly, since it ought not to be an accepted guest in our habitations—breeds by preference in horse manure but will lay its eggs in almost any kind of moist-decaying organic matter. The larvæ which hatch from these eggs are whitish maggots which crawl about and feed in the manure or other material for five days to a week and then burrow down into the ground or out into the dry edges of the manure heap where they go into the pupa stage, a little brownish chrysalis, like that which we find inside the cocoon of a moth. From this pupa after a few more days the adult fly emerges.

The control of the fly, therefore, depends on the elimination of decaying organic matter in which it may breed, and particularly on the care of stable manure, which should be stored in covered tight-bottomed bins from which the larvæ can not escape and removed from the vicinity of human habitation at least once a week. Adult flies may be reduced in numbers by the use of traps which are made with a wire cone having some attractive bait below and opening at its smaller end into a cage of wire. The flies after seeking the bait pass upward through the cone toward the light into the cage and are unable to find their way out again. Screening of windows and the use of fly paper and fly poisons are useful palliatives, but "swatting the fly" is an ineffective procedure and the only real solution of the problem lies in the systematic and rigorous control of the

sanitary conditions which make continued fly-breeding possible.

Mosquitoes and Malaria

The most important of the insect-borne diseases from a world-wide viewpoint, and considering sickness and disability as well as direct mortality, is no doubt malaria, which Sir William Osler, the great physician, justly called "the greatest single destroyer of the human race." The secret of this mysterious malady—the bad air disease (*mal' aria*)—was revealed in 1898 when it was discovered that the infecting germ was transmitted by the bite of mosquitoes of the genus Anopheles, and in no other way. Its connection with night air, marshy areas, and excavated soil was at once explained by the fact that these mosquitoes breed in stagnant water, and there was placed within our grasp a simple and effective method of controlling this disease through measures directed against its insect host.

The eggs of the mosquito are laid upon the surface of the water, and the larvæ which hatch out are little brownish or blackish wigglers which jerk themselves about in the water in a characteristic fashion and come up to the surface to breathe. After a few days the larvæ change to pupæ, little seed-like objects which still move about actively but do not feed, and from these pupæ the adult mosquitoes emerge, standing on the floating pupa skin at the surface of the water until their wings have dried and they can fly away.

If one is troubled with mosquitoes it is a simple matter to search out their breeding places by hunting for small protected bodies of standing water, clogged streams, flooded areas, pools, rain barrels, roof gutters, and the like, and dipping up water in a white lined vessel to see whether it contains wigglers.

The Anopheles larvæ can be distinguished from the larvæ of the common mosquito, Culex, by the fact that when resting at the surface of the water they lie parallel with it, while the Culex larvæ hang down at an angle, touching the surface only with their long breathing tubes. The adult mosquitoes are also easily distinguished by the fact that Anopheles has spotted wings and Culex, clear wings, and by their resting position on a wall, Culex standing in a slightly humped position, its head pointing toward the wall and its body parallel with it, while Anopheles stands at an angle with the wall, beak, head, and body all in a straight line.

The most effective way of controlling mosquitoes is obviously to drain the marshes and remove all the small accumulations of stagnant water, for these insects will not breed in large open ponds or clear flowing streams. Where drainage is unduly costly the wigglers may be destroyed by spraying oil on the marsh lands, since the oil spreads in a thin layer over the surface, and makes it impossible for the insects to get to the air to breathe, or by stocking small ponds with fish which eat the wigglers. Screening of houses is of great assistance in the control of malaria, and we have still another means of combating this disease by the systematic use of quinin to cure those who are ill, to eliminate the germs from the blood of carriers, and to protect those who are well against their entrance.

The International Health Board has carried on a series of striking demonstrations of the value of malaria control measures in various southern States and tropical countries and has demonstrated that by the control of mosquito breeding areas, by screening, or by the systematic use of quinin, it is possible to eliminate from four-fifths to nine-tenths of the

malaria in the worst infected districts at a cost which generally amounts to between fifty cents and a dollar per inhabitant a year. The money loss due to malaria in the United States has been estimated at $100,000,000 a year, and it is obvious that it will prove well worth while from a purely economic standpoint to take vigorous steps to eradicate this disease and lift the burden of disability which it lays upon the shoulders of our southern populations.

The Conquest of Yellow Fever

The discovery of the mode by which malaria is transmitted opened the way for the most dramatic episode in the history of public health—the conquest of yellow fever. The disease, since the days of the ancient Maya civilization, had been the curse of tropical America. From this region of endemic prevalence it spread to the United States in every year between 1800 and 1879 with but two exceptions. In 1793, a tenth of the population of Philadelphia perished from its ravages. When the American Army of Occupation entered Cuba in 1898, yellow fever was one of the major problems with which it was confronted, and the origin of the disease was still a complete mystery. In the words of a report issued by the United States Public Health Service in that year "one has not to contend with an organism or germ which may be taken into the body with food or drink, but with an almost inexplicable poison so insidious in its approach and entrance that no trace is left behind."

At this very time, however, the mosquito theory of the transmission of malaria had just been established. When a commission of army surgeons, including Reed, Carrel, Lazear, and Agramonte, was sent to Havana in 1900 they naturally turned to a similar ex-

planation for the causation of yellow fever. What followed has been elsewhere described in the following words:[1]

"The lower animals were not known to suffer from yellow fever, so that experiments upon human subjects were essential. In the words of Dr. Kelly's life of Major Reed, 'after careful consideration, the Commission reached the conclusion that the results, if positive, would be of sufficient service to humanity to justify the procedure, provided, of course, that each individual subjected to experiment was fully informed of the risks he ran, and gave his free consent. The members of the Commission, however, agreed that it was their duty to run the risk involved themselves, before submitting any one else to it.'

"The first successful experiment was made with Dr. Carrel, who allowed himself to be bitten on August 27 by a mosquito which had previously bitten four yellow fever patients. Four days later he was taken sick and for three days his life hung in the balance. Both he and Private W. H. Dean, the second case produced experimentally in the same way, recovered. Dr. Lazear, however who came down with the disease, not as a result of the experimental inoculations to which he also had submitted, but from an accidental bite, was less fortunate than his colleagues, for a week later he died, after several days of delirium.

"An experimental station, named 'Camp Lazear' after this first martyred member of the party, was established in the open country; and to the lasting honor of the United States Army, volunteer subjects for the experiments from among the troops were always in excess of the demand. Private John R.

[1] Winslow, C.-E. A. "The Evolution and Significance of the Modern Public Health Campaign." Yale University Press. New Haven, 1923.

Kissinger and John J. Moran, a civilian employee, were the first to volunteer 'solely in the interest of humanity and the cause of science,' their only stipulation being that they should receive no pecuniary reward.

"The result of the experiments carried out at Camp Lazear proved beyond peradventure that yellow fever was transmitted by the bite of a certain mosquito, *Aëdes calopus*, and in no other way, for non-immunes who lived for twenty days in a small, ill-ventilated room, in which was piled clothing and bedding, loathsome with the discharges of yellow fever patients, all escaped infection, so long as they were protected from the bites of mosquitoes.

"On the memorial tablet to Lazear in the Johns Hopkins Hospital is the inscription: 'With more than the courage of the soldier, he risked and lost his life to show how a fearful pestilence is communicated, and how its ravages may be prevented.' The same risk was freely taken by each member of the party from major to private. The result of their devotion is indicated in two of Reed's letters to his wife: 'Six months ago, when we landed on this island, absolutely nothing was known concerning the propagation and spread of yellow fever—it was all an unfathomable mystery—but to-day the curtain has been drawn'; and later, on New Year's Eve; 'Only ten minutes more of the old century remain. Here have I been sitting reading that most wonderful book, "La Roche on Yellow Fever," written in 1853. Forty-seven years later it has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and to put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old cen-

tury. May its cure be brought out in the early days of the new.'

"The practical result of this discovery was immediate and striking. In the half-century or so for which we have records, yellow fever had killed an average of 750 persons a year in the City of Havana. The sanitary reforms introduced by the American Army of Occupation which produced good results in reducing typhoid and smallpox had been powerless against yellow fever because its cause was as yet a mystery. Following immediately on the experiments at Camp Lazear, on February 15, 1901, a campaign was begun on the new lines indicated, by screening the rooms occupied by yellow fever patients and destroying all mosquitoes in the neighborhood. As a result there were six deaths in the City of Havana during the year 1901 as against 305 in the preceding year, and altho sporadic cases have been introduced from other localities, yellow fever has never again established itself in Havana. The scourge of centuries was wiped out in a single year.

"It was the demonstration of yellow fever control at Havana which, four years later, made possible the building of the Panama Canal; and throughout the Torrid Zone has opened up the Tropics for the occupancy of the white race. During the last few years the International Health Board has actively embarked upon the aggressive warfare of extermination against yellow fever outlined by the late General Gorgas. At Guayaquil, once the chief endemic center of this disease, it has been eradicated. During 1921, Honduras, Nicaragua, Ecuador, and Costa Rica were immune from the disease; Guatemala and Salvador had no cases later than February; by July, Peru, and by November, British Honduras were free of infection. The complete eradication of yellow fever from the earth is within the bounds of our vision."

Plagues of the Olden Time

Scarcely less spectacular than this victory over yellow fever is the success which modern sanitary science has made possible in dealing with the two great pestilences of the Middle Ages, typhus fever and bubonic plague.

Typhus fever, the "ship fever," "camp fever," and "jail fever" of olden times, is the disease which decimated the troops of Napoleon in the retreat from Moscow and which constantly hung like a black cloud along the track of armies. With increasing habits of personal cleanliness this disease gradually disappeared from civilized communities but continued to smoulder in southeastern Europe, in Mexico, and in other backward areas of the globe. With the outbreak of the Balkan Wars typhus developed to grave epidemic proportions in Serbia, but in 1909 Nicolle discovered that this disease was transmitted by the bite of the body louse, and it was clear that a simple routine of cleansing bodies and clothing could be relied upon to check its ravages. Throughout the Great War typhus was kept under control—to burst out once more in gigantic conflagration with the breakdown of civilization in revolutionary Russia. In 1921, the whole world was menaced with an invasion more deadly than that of the Red Armies; but in Poland, where the principal battle line was set, the Polish Sanitary Administration, aided by the Epidemic Commission of the League of Nations, established quarantine stations, disinfecting plants, and hospitals which were completely successful in checking the westward spread of the disease.

In similar fashion the progress of sanitary science has robbed bubonic plague of its terrors. This disease, the "Black Death" of the Middle Ages, has twice spread over the whole of the known world, killing one-fourth of the population of Europe in

the fourteenth century, and in 1665 producing in London the horrors immortalized by Defoe in his Journal of the Plague Year. In 1871, plague again broke out in China and Eastern Siberia and passed on to India, where it killed six million victims in a period of ten years. This time, however, it confronted a new force, the organized force of modern science. In Japan, the germ was discovered, and it was shown that the plague was primarily a disease of rats, marmots, ground squirrels, and similar animals. In India, it was shown that the germ is transmitted from rat to rat and from rat to man by the flea. The modern method of plague control is built chiefly upon the eradication of rats, by trapping, poisoning, and above all by eliminating rat-breeding places, and upon a system of quarantine which includes the destruction of rats upon ships coming from infected ports. During the past twenty years plague has at times spread to ports all over the world —in Australia, in England, in Brazil, in Texas, Louisiana, and California. In certain parts of California the ground squirrels have become infected so that a permanent focus of plague exists in this country. Yet everywhere, except in India, the disease has been held in check by vigorous anti-rat campaigns wherever a human case occurs or a rodent case in the vicinity of human habitations. In no well-organized community have we to-day the slightest fear of a real plague epidemic.

So far as all the insect-borne diseases are concerned, it may, indeed, be said that they are now wholly within our control. The endemic centers of plague, typhus, and malaria are more widespread than those of yellow fever, and complete eradication of these diseases from the surface of the globe may not be within the immediate bounds of possibility.

In any given community, however, we know exactly what to do in order to hold these diseases in check, and their control depends simply on the appropriation of the necessary funds and their expenditure by qualified sanitary authorities.

CHAPTER IV

THE CONTACT-BORNE DISEASES

Nature and Significance of Contact Infection

WITH the progressive control of foods and of insects as vehicles of disease, the relative importance of the third mode of infection—by more or less direct contact—has come to occupy more and more of the attention of the sanitarian; and unfortunately the difficulties in the way of control are here very much greater than in the case of either of the other two groups.

The paths by which contact infection may spread are almost infinite in number. The most direct type of transfer is that which occurs when an infected person coughs or sneezes in the face of a susceptible victim, as may happen whenever people are crowded together, in a street car or in some congested place of public assembly. From such an extreme case we pass through innumerable more roundabout types of transfer in which germs pass from the mouth of the infected person to the hands of the infected person, thence to various objects, such as door knobs, faucets, push buttons, money, and the like, and finally to the hands of the new victim or to some article of food and back to the mouth again. As we have pointed out in an earlier chapter there is no sharp line to be drawn between contact and fomites infection. The only essential for the dissemination of disease is that the discharges from one mouth shall be carried to another mouth without too considerable a lapse of time.

As Dr. C. V. Chapin has pointed out:[1] "Probably the chief vehicle for the conveyance of nasal and oral secretions from one to another is the fingers. If one takes the trouble to watch for a short time his neighbors, or even himself, unless he has been particularly trained in such matters, he will be surprised to note the number of times that the fingers go to the mouth and the nose. Not only is the saliva made use of for a great variety of purposes, and numberless articles are for one reason or another placed in the mouth, but for no reason whatever, and all unconsciously, the fingers are with great frequency raised to the lips or the nose. Who can doubt that if the salivary glands secreted indigo the fingers would continually be stained a deep blue, and who can doubt that if the nasal and oral secretions contain the germs of disease these germs will be almost as constantly found upon the fingers? All successful commerce is reciprocal, and in this universal trade in human saliva the fingers not only bring foreign secretions to the mouth of their owner, but there, exchanging them for his own, distribute the latter to everything that the hand touches. This happens not once but scores and hundreds of times during the day's round of the individual. The cook spreads his saliva on the muffins and rolls, the waitress infects the glasses and spoons, the moistened fingers of the peddler arrange his fruit, the thumb of the milkman is in his measure, the reader moistens the pages of his book, the conductor his transfer tickets, the 'lady' the fingers of her glove. Every one is busily engaged in this distribution of saliva, so that the end of each day finds this secretion freely distributed on the doors, window sills, furniture, and playthings in the home, the straps of trolley cars, the rails and counter and desks of

[1] Chapin, C. V. "The Sources and Modes of Infection." John Wiley and Sons. New York. 1910.

shops and public buildings, and, indeed, upon everything that the hands of man touch. What avails it if the pathogens do die quickly? A fresh supply is furnished each day."

The intestinal diseases, such as typhoid fever, may be, and often are, transmitted by direct contact, since polluting material from the intestinal discharges by no means infrequently finds its way to the fingers. The contact-borne diseases *par excellence* are, however, those in which the specific germs are present in the discharges from the nose and throat; and a moment's consideration will indicate that in this class are included the great majority of the communicable diseases with which we have to deal. Discharges from the upper respiratory tract are the primary sources of infection, not only in such diseases as the common cold, diphtheria, influenza, mumps, pneumonia, septic sore throat, tuberculosis, and whooping cough whose symptoms are obvious in throat, nose, and lungs, but also in the eruptive diseases, chickenpox, German measles, measles, scarlet fever, and smallpox, and in infant paralysis and epidemic cerebrospinal meningitis where the seat of the actual disease is in the central nervous system.

The control of the diseases spread by contact dissemination of the discharges from the upper respiratory tract is, therefore, the major problem of modern epidemiology (the science of studying epidemics). Its solution can not be attained by any simple procedure such as the pasteurization of milk or the drainage of mosquito breeding marshlands; but only by the far more difficult task of detecting and isolating human cases and carriers of disease.

Isolation and Quarantine

The control of the contact-borne diseases by the application of intensive and scientific methods of iso-

lation and quarantine is one of the most important and responsible functions of the health department of city or town; and the fulfilment of this function depends upon the whole-hearted and intelligent cooperation, not only of the medical profession, but of the general public as well.

The first essential is, of course, that the health department should be notified of the existence of cases of communicable disease, which may prove a source of infection for others, at the earliest possible moment. For this reason Sanitary Codes usually provide that physicians, teachers, householders, and others shall report all cases of disease that are "presumably communicable" without even waiting for a final diagnosis to be made. In many instances, as in diphtheria, typhoid fever, tuberculosis, and malaria, the Health Department laboratory can provide invaluable assistance in establishing the diagnosis by special laboratory tests.

As soon as a case of communicable disease is discovered it is the duty of the Health Department to establish isolation—that is, to see that the case is so cared for as to give every possible security against the transmission of the infective material. In all the more serious and acute diseases, such as diphtheria, typhoid fever, scarlet fever, measles, pneumonia, infant paralysis, and epidemic cerebrospinal meningitis, the room occupied by the patient must be maintained as an isolated area, no one being permitted to enter it unnecessarily, and absolutely no one, except the doctor and the nurse or other attendant, being permitted to approach near to the patient or to touch anything in the room. The infected bodily discharges of the patient—in bed-pans, or on handkerchiefs as the case may be—and all objects and surfaces soiled with such discharges, such as bedding, eating utensils, and the like, should be disinfected according to rules

laid down by the Health Department. Nothing should leave the room until it has been thus disinfected, and, above all, the hands of the nurse or other attendant should be thoroughly washed with a disinfectant solution before leaving the room or touching anything that is to be carried out of the room. Success in preventing the spread of communicable disease depends first and foremost upon such daily and hourly care, and it is upon the attendant upon the sick, whether nurse or relative, that the real responsibility must rest. Where such isolation as that described can not be secured in the home, it is the duty of the Health Officer to remove the case to a hospital where adequate care is possible.

In the case of certain diseases, like mumps and whooping cough, in which the patient is not sick enough to be in bed, and against which grown people are generally more or less immune, such elaborate precautions are impracticable and unnecessary. In such diseases the Sanitary Code usually provides merely that affected children shall remain out of school and be kept away from places of public assembly and, in general, from other children during the period of isolation.

The length of time for which isolation need be continued varies in different diseases. Irrespective of any time limit, isolation must always be maintained until all active symptoms, such as discharging ears, have ceased. In whooping cough, however, the cough is an after effect which often persists long after the active disease process has ceased. It is most important that isolation regulations should be made as little burdensome as is consistent with safety. In diphtheria, cerebrospinal meningitis, and typhoid fever, the disappearance of the infecting organism can be established by laboratory tests. In the other common diseases we rely on an arbitrary time limit which

experience has shown to be satisfactory. The standard isolation periods are as follows: chicken-pox, until primary scabs have disappeared; German measles, eight days from onset; measles, seven days from onset; mumps, until glands have returned to normal size; infant paralysis, twenty-one days from onset; scarlet fever, twenty-eight days from onset; smallpox, until disappearance of all scabs and crusts; whooping cough, four weeks from onset or two weeks from first characteristic whoop.

When the isolation period is over, the patient may be discharged and the room given a final thorough cleansing. Fumigation is unnecessary and useless except in the insect-borne diseases. If daily disinfection has been carried on during the course of the disease the few germs which may have escaped immediate destruction will have died out with the lapse of time; and, if the isolation procedures have not been effectively practised, infection is already fairly certain to have spread to susceptible members of the family.

Quite as important as the care of the first case of disease is the supervision of other members of the family, schoolmates, or associates, who have been in contact with the patient and may already have become infected by him before his condition was recognized. It happens, unfortunately, that many diseases, like measles and whooping cough, are particularly catching in the very early stages, so that it is too late when they are detected to prevent the transfer of infection to a second crop of cases. By careful supervision of the contacts it is generally possible, however, to prevent the transmission of disease to a third and still larger group; and this is one of the main objectives of modern epidemiology.

The duty of the health officer is to exclude these contacts from school and places of assembly and to

keep them under observation until it is certain that they are not coming down with the disease. In some diseases, like diphtheria and epidemic cerebrospinal meningitis, we can discover by taking cultures whether a contact case is a carrier or not. In other instances the contacts should be quarantined for the incubation period of the disease—that is, the period which elapses between the time of infection and the first obvious signs of illness—unless they are known to be immune as the result of a previous attack. In cerebrospinal meningitis, this period is 2 to 10 days; in chicken-pox, 14 to 21 days; in diphtheria, 2 to 5 days; in German measles, 10 to 21 days; in measles, 7 to 18 days; in mumps, 4 to 25 days; in poliomyelitis, 3 to 10 days; in scarlet fever, 2 to 7 days; in smallpox, 12 to 14 days; in typhoid fever, 7 to 23 days, and in whooping cough up to fourteen days. Where a contact is known to be immune as a result of a previous attack the regulations need not generally be enforced. The greatest care should be taken to watch contact cases which are in quarantine and to enforce isolation if any symptoms suggestive of communicable disease occur.

The Sanitary Conscience and the Aseptic Sense

In view of the fact that many of the common communicable diseases, measles and whooping cough, for example, are particularly contagious in the very early stages before a real diagnosis is possible, it is of urgent importance to secure the intelligent cooperation of the general public in their control. In particular school teachers and mothers of young children should be on the lookout for the symptoms generally associated with some infection such as coughing, sneezing, running nose or eyes, feverishness, headache, rashes of any kind, looseness of the bowels, or

vomiting. Such symptoms may mean much or little; but whenever they appear children should be kept out of school and away from contact with their fellows and the doctor should be called if illness continues. We need to develop what I have elsewhere called "the sanitary conscience," a recognition of the serious responsibility which is incurred by exposing other people to infection with any communicable disease, even the common cold. In the conduct of the important affairs of daily life it is sometimes necessary to take risks, but it is a sign of thoughtless folly rather than strength of will for people who are coming down with some disease to attend places of public assembly or pleasure parties.

Above all, it is essential that infants and young children should be protected from exposure. The old saying, that a child must have these diseases sometime and the sooner they are over the better, is a dogma which has slain its thousands and its tens of thousands. The fatality of measles and whooping cough is five times as great in infants under one year of age as in children over five; every month and every week for which infection can be postponed is so much gained in reducing the danger of a fatal result.

For those who are well, the surest safeguard against communicable disease lies in the development of "the aseptic sense," an instinctive habit of keeping things that are not clean away from the mouth and nose and from the standpoint of bacteriology everything that has not been specially cleansed must be regarded as a possible source of danger. It is an unpleasant truth that every time we come down with a cold it is because we have put the discharges from some one else's mouth or nose into our own, and the actual carrying out of the following two simple rules would probably do more than

anything else for the prevention of communicable disease.[1]

I. Nothing should ever go into the mouth except things to eat and drink and the toothbrush. Nothing should ever go to the nose except a clean handkerchief.

II. The hands should be thoroughly washed before meals and before eating any food handled with the fingers.

[1] See also "Personal Hygiene," by A. J. McLaughlin, M.D., in the National Health Series.

CHAPTER V

THE ARTIFICIAL CONTROL OF IMMUNITY

Vital Resistance and Immunity

IN the preceding chapters we have discussed the more important methods by which the entrance of disease germs into the human body may be prevented. When these primary defenses have failed there begins a second stage of the struggle, carried on within the body itself, and here, too, the science of bacteriology is able to intervene, and often in a complete and decisive fashion.

The outcome of the battle between an invading germ and the defensive mechanism of the body is in part decided by the condition we term vital resistance. The factors included under this heading may be of widely different kinds. The fowl, for example, can not be inoculated with the disease called anthrax because its normal body temperature is above the temperature at which the anthrax germ can grow; but Pasteur succeeded in giving fowls anthrax by chilling them in a bath of ice water. Krause and his associates have recently demonstrated that the course of tuberculosis in the rabbit and the guinea-pig is substantially different and that this difference is due to the details of the anatomical structure of the lung in the two animals. Among human beings we are all familiar with the fact that vital resistance depends in large measure upon general vitality and that tuberculosis and pneumonia are likely to develop (provided the specific germs be present) if the vital resistance is weakened by exhaustion, underfeeding, or a previous attack of some other disease.

Quite distinct from this sort of general vital resistance is the specific immunity which almost universally follows an attack of some communicable disease. When a person recovers from almost any such infection he will have acquired an immunity which protects him against another attack, sometimes only for a few weeks but frequently for life. Such acquired immunity may be developed through attacks of disease so slight as to be scarcely noticeable or quite overlooked, and investigations, to which reference will be made later on, have shown that a very large proportion of the population gradually acquires immunity against diseases like diphtheria and tuberculosis through the occurrence of such very light attacks. When a new disease is introduced into an unprotected community, as when measles was brought to the Faroe Islands or when Indian and African troops in France during the war were exposed for the first time to tuberculosis, the rapidity and the fatality of the disease may be astounding.

It is obvious that if we had some way of producing such specific immunity at will and without waiting for a natural attack to occur, in mild or in severe form, we should possess a most potent weapon in the war against disease. In a number of the communicable diseases exactly this result has been accomplished by the procedures of vaccine and serum treatment, and the number of diseases in which it can be attained is increasing year by year.

Smallpox and Vaccination

The first example of successful control of a communicable disease through the creation of specific immunity was the practise of vaccination against smallpox introduced by Jenner a century and a quarter ago. It is difficult for us to realize the terrors of smallpox in the days before this discovery

was made. Its ravages were almost universal, and about one person in every ten died of the disease. An English health officer of this period quaintly and correctly classified the citizens of his town by saying that so many had had smallpox, so many were at the moment having smallpox, and so many (the rest of the population) were still to have smallpox. As Macaulay says:

> "That disease over which science has since achieved a succession of glorious and beneficent victories, was then the most terrible of all the ministers of death. The havoc of the plague had been far more rapid; but plague had visited our shores only once or twice within living memory; and the smallpox was always present, filling the churchyards with corpses, tormenting with constant fears all whom it had not yet stricken, leaving on those whose lives it spared the hideous traces of its power, turning the babe into a changeling at which the mother shuddered, making the eyes and the cheeks of the betrothed maiden objects of horror to the lover."

The practise of inoculation against smallpox which depended on the production of immunity by inoculating the individual with the material from the pustules of a smallpox patient, had been in vogue in Asia for at least three centuries before the Christian era, and was finally introduced into England in 1718 by Lady Mary Wortley Montagu, the brilliant wife of the British Ambassador at Constantinople. The reaction to this treatment was often severe and sometimes fatal and it had little effect upon the general prevalence of the disease. That it should have been practised at all is striking evidence of the universal prevalence of smallpox and the horror which the disease inspired.

It was in 1796 that Edward Jenner gave us the modern practise of vaccination, which possessed all

the advantages of inoculation without its dangers. His discovery was made in the following way: In the rural district in which he lived many of the cattle were infected with a mild eruptive disease known as cowpox, and this disease was often contracted by the men and girls who milked the cows. There was a common belief that those who had had the cowpox were resistant against smallpox, and this theory Jenner tested out by vaccinating a boy, James Phipps, with cowpox material and then inoculating with true smallpox matter, in the fashion generally practised at the time for protection against natural smallpox. The cowpox vaccination "took"; the smallpox inoculation failed to "take," showing that the vaccination had produced in the boy an effective immunity against the smallpox germ. During the years 1799–1801 over 3000 different persons were thus vaccinated, and then inoculated, at the London Small-Pox Hospital with the demonstration of complete protection in every case. There is perhaps no other procedure in medicine which rests upon so ample and sure a basis of direct experimental evidence.

Since Jenner's day it has been shown that the inoculation of human smallpox material into the cow produces cowpox, and that by exposure to the body fluids of the cow the germ of smallpox has permanently lost its power to produce smallpox. Vaccine retains, however, the power to stimulate the human body so that it becomes immune against the virulent disease. The effect is not life-long or absolute. It wears off with the passage of time, so that vaccination should be repeated about once in seven years. Yet even among those who have been vaccinated long before, the great majority resist infection and those who do contract the disease suffer in a relatively mild degree. Statistics for a group of English towns showed, for example, a rate of 35 deaths

per 100 cases among the unvaccinated, and only 5 deaths per 100 cases among the vaccinated.

A study of the general statistical results of the use of vaccination offers conclusive evidence in regard to the efficacy of the process. As soon as the practise of vaccination was introduced in the various countries of Europe, the terrible death rates of the nineteenth and preceding centuries ceased. In Sweden, the death rate for the twenty-eight years before vaccination was 2,050 per million, and for the forty years following vaccination 158 per million. The death rate in various countries corresponds to the prevalence of vaccination. Even as late as 1893–97 the smallpox rate was over 90 per million in incompletely vaccinated countries like France, Belgium, and Austria, rising to 463 in Russia and 563 in Spain, while in well-vaccinated Germany and in the Scandinavian countries the rate has been 1 or less for the last half century. During the eight years before the American army entered Havana, and before vaccination was enforced, there were 3,132 deaths from smallpox in the city; during the next eight years there were seven. In 1905 and 1906 over three million vaccinations were performed in the Philippine Islands with the result that a toll of 40,000 deaths a year was changed to a few hundreds; the latter occurring in remote places which had not been reached with fresh and potent vaccine. In the provinces immediately adjacent to Manila there were 6,000 deaths a year from smallpox before vaccination and none after. When the health service of the Philippines was turned over to native officials in 1914, vaccination was neglected, and as soon as enough susceptible children had been added to the population the disease broke out once more. In 1918 there were again 50,000 deaths from smallpox in the Philippines, *nine-tenths* of them among the unvaccinated children.

There are unfortunately many communities in the United States which are heading straight for an experience like that of the Philippine Islands through neglect of the safeguard of vaccination. In 1916 there were 15,450 cases of smallpox with 48 deaths; in 1920 there were 94,691 cases with 366 deaths. We shall, no doubt, have some striking demonstration of the folly of neglect of vaccination during the next ten years; but any community which desires to do so can stamp out smallpox and keep it under control by the practise of vaccination and revaccination.

The Scientific Principles of Vaccine Treatment

Jenner's discovery was purely an empirical one and limited to the particular disease with which he dealt. It remained unique for three-quarters of a century until Pasteur worked out the fundamental principles upon which the whole modern development of vaccine and serum treatment has been based.

It was in connection with a disease of fowls, known as chicken cholera, that Pasteur made his first discoveries along this line. He had isolated the germ of this disease and proved that it could be produced at will by the inoculation with this germ of susceptible birds. On one occasion he used an old laboratory culture for this purpose and found that it had become so weakened by long standing that the fowls no longer developed the typical disease; but when some of these same fowls were later inoculated with a fresh virulent culture they were found to have developed an immunity against its attack. The fertile mind of Pasteur at once grasped the possible analogy between this phenomenon and that of Jennerian vaccination. Was it possible, as a general method of controlling communicable disease, to prepare weakened or attenuated viruses which would be robbed of

the power of harm but would retain the ability to stimulate the body so as to produce in it a state of immunity similar to that following an actual attack of disease?

Pasteur's next step was taken in connection with a disease of cattle known as splenic fever. After many eager and anxious months he succeeded in producing a vaccine for this disease, this time by exposing the germs to heat, a vaccine so effective that it would confer an almost complete immunity without harming the treated animals. On May 5, 1881, a public demonstration of this new procedure was given at the farm of Pouilly le Fort near Melun, as a result of the challenge of the skeptical editor of a veterinary paper. Twenty-five sheep and six cows were inoculated with the protective vaccine, and after a suitable interval these animals and a similar group of untreated ones were inoculated with the virulent virus of splenic fever. The final inoculation took place on May 31, and altho Pasteur had boldly predicted, "The twenty-five unvaccinated sheep will all perish; the twenty-five vaccinated ones will survive," he was a prey to intense anxiety when the crucial test came. On the morning of June 2, however, a telegram arrived from the once hostile veterinarian, announcing "stunning success," and when Pasteur arrived at the farm in the afternoon amid the acclamation of the delegates from medical and veterinary and agricultural societies who crowded about the enclosure, twenty-two of the unvaccinated sheep were dead and two others were breathing their last, while the vaccinated animals were all in perfect health.

By this demonstration, the broad principle was established that the production of immunity by the injection of weakened germs or killed germs or extracts from dead germs is indeed a general and not an isolated phenomenon; and the way was opened

for one of the most brilliant chapters in the history of public health, a chapter which is still in the course of writing at the present day.

The Development of Vaccine Prophylaxis

The first practical application of this new principle was made by Pasteur himself in the development of a vaccine for the treatment of rabies. In general, vaccines are used for the prevention rather than the cure of disease—that is, the vaccine is administered to well people whom we wish to protect against the danger of a future attack. The reason for this is that the immunity produced by a vaccine takes a considerable time to develop. Where an infection is localized in some special part of the body, as in the case of a carbuncle, for example, the use of a vaccine may aid in recovery by summoning up the resources of the rest of the body to repel the local attack. In the case of rabies there is another apparent exception to the general rule, since this vaccine is given to patients who have been bitten by a rabid animal. This is really, however, a preventive rather than a curative measure because it takes a long time (days or weeks) for the infective agent of rabies to find its way from the wound where it was introduced to the central nervous system where the disease is actually produced; and during this time the vaccine has an opportunity to develop a condition of immunity.

The vaccine for rabies is produced by drying the spinal cord of an animal inoculated with the disease, thus attenuating the germ which is present in the spinal tissues. First applied successfully by Pasteur in 1884, this vaccine reduced the fatality among persons bitten by a rabid animal from about ten per cent. to a fraction of one per cent., and its use at the Pasteur Institute in Paris alone has saved nearly 3000 lives.

A vaccine for cholera was prepared by Haffkine in India in 1895, and between 1896 and 1898, Pfeiffer and Kolle in Germany, Wright in South Africa, and Russell in the United States developed a highly effective vaccine for the prevention of typhoid fever. This is prepared in a very simple fashion by heating a culture of typhoid bacilli to a point which will kill the germs without destroying their immunizing power and it is nowadays the practise to use a mixed vaccine which will protect against the two forms of paratyphoid fever as well, three doses of the mixed vaccine rendering one immune against these two diseases and typhoid fever as well. By the application of vaccine treatment the typhoid rate in the United States Army was reduced to one-tenth of its former figure between 1909 and 1914; and the freedom of the armies from this disease during the Great War was chiefly due to the use of this preventive.

Active investigations are being carried on with the object of preparing vaccines for other diseases with more or less significant success, and with much promise for the future. There is a good vaccine for plague; a vaccine which is extensively used, but of somewhat problematical value, for whooping cough; and Dreyer in England has a vaccine, for which he and his associates entertain high hopes, to be used in the treatment of tuberculosis. Perhaps the most hopeful line of research which is being actively prosecuted at present is that which leads to the preparation of vaccines for pneumonia. There are already vaccines which appear to be useful in dealing with certain forms of this disease, and Huntoon has recently prepared a new type of vaccine which may, perhaps, have a much wider field of usefulness.

We have so far spoken only of the most characteristic form of immunity, that which is specifically related to a particular disease. It should be men-

tioned that the studies of the last five years have indicated that there is a certain degree of *non-specific* immunity produced by an attack of one communicable disease but effective to some extent against other types of infection. In general, among the drafted men who were collected in our army camps in 1917 and 1918 the recruits from the cities showed a much higher resistance against communicable diseases in general than did those from the rural districts, largely, as is believed, on account of non-specific immunity due to greater exposure to various infections during the period of childhood.

The Use of Immune Sera in the Treatment of Disease

Vaccines, as we have seen, are substances containing principles derived from a disease germ, which when introduced into the human body stimulate the body cells to the production of a state of active immunity. Such an active immunity is generally more or less permanent, but it takes time to become manifest. Therefore, vaccines are commonly used for the prevention of disease rather than for cure.

If, however, we can vaccinate an animal against some disease, common to animals and men, and produce in it a state of active immunity; if then we can withdraw some of the blood of the animal containing the immune principles, it should be possible to inject the animal blood serum containing such principles directly into the body of a patient suffering from the disease in question so as to neutralize the poison produced by the invading germ and thus to favor recovery by producing an immediate tho temporary passive immunity. This feat was first accomplished by Behring and Kitasato and their associates in 1890 in the case of diphtheria and tetanus; and to-day we

have a whole group of immune sera which can be used in this way.

In the case of diphtheria, for example, the toxin, or specific poison, of the diphtheria bacillus is injected into the horse in gradually increasing doses, until the horse is able to sustain a dose several thousand times as great as that which would prove fatal to an untreated animal. During this period the tissues of the horse have been producing larger and larger amounts of diphtheria antitoxin (a substance which specifically neutralizes the toxin). The horse is then bled, and the clear blood serum, containing the antitoxin, is separated, purified, and standardized. If this antitoxic serum be used at a sufficiently early stage of the disease, recovery is practically certain; and the effect of its use has been to cut down the death rate from diphtheria in the general population to less than one-fourth of what it was before this treatment was available.

We have to-day immune sera of proved effectiveness, not only for diphtheria and tetanus, but for plague, dysentery, epidemic cerebrospinal meningitis, certain forms of pneumonia, and yellow fever. The serum for cerebrospinal meningitis has cut down the fatality from this disease from seventy-five per cent. to twenty-five per cent. In the case of pneumonia we have to deal in reality with several different diseases, due to distinct types of bacteria but having symptoms more or less in common. For pneumonia caused by certain of these organisms we have sera which will substantially reduce mortality; for pneumonia of other types we have as yet no such weapons at our disposal.

Even in the case of diseases which are not common to man and the lower animals the principles of serum therapy may be applied by the treatment of one human case with immune blood derived from another

human case which has recently recovered from an attack. Such a procedure has been used with success in pneumonia, scarlet fever, measles, and mumps; and here, too, there is reason to hope for substantial new developments in the future.

The Challenge of Diphtheria

In connection with this general subject of vaccine prophylaxis and serum therapy the problem of diphtheria deserves special and more detailed consideration. In dealing with this disease we possess a more complete machinery of control than is available in the case of any other communicable malady. Much has been accomplished already in reducing th diphtheria death rate; but the important place which this disease still holds among the causes of mortality is a constant reproach to the medical and public health professions.

In the first place, we can detect the carriers of the diphtheria bacillus with certainty by a simple bacteriological examination. In the second place we can determine whether a given individual is already immune against diphtheria or not by what is known as the Schick test. In this test a very minute amount of diphtheria toxin is injected into the skin, and if the person is immune no reaction occurs, while if he is not immune a characteristic reddened area develops. Thirdly, we can cure diphtheria when it has begun to develop, by the use of antitoxin; and, finally, we can protect those who have not yet become infected and are not already immune by the injection of a mixture of toxin and antitoxin which acts as a vaccine in stimulating the development of a state of active immunity against the disease.

When a case of diphtheria occurs it is a simple matter to test all those who have been in contact with the case by bacteriological culture and by the Schick

test. Those who are already immune and not carriers need no further attention. Those who are immune but have diphtheria bacilli in their throats should be isolated for the protection of others. Those who are susceptible but not carriers should be given toxin-antitoxin to protect them against possible future infection; those who are carriers and susceptible should be isolated and given antitoxin, since they are in immediate danger.

It is better policy to take measures to protect children against diphtheria without waiting till a case actually appears in their family or school room. In New York and many other cities campaigns have been carried out on an extensive scale for the Schick testing of the general school population in order to determine which children are already immune and to immunize those who are not, with the toxin-antitoxin mixture. These wholesale tests have brought out the very interesting fact that infants of three months or less generally possess a temporary immunity inherited from the mother. The proportion of immune infants drops from 85 per cent. during the first three months to only 30 per cent. in the second year as this inherited immunity wears off. From this point the proportion of immune children gradually increases, in New York City up to 85 per cent. again after twenty years of age, no doubt as a result of slight unnoticed infections which often occur in crowded communities. In rural districts and in certain private schools where children are protected from chance exposures the proportion becoming immune will be very much less. The use of toxin-antitoxin for protecting non-immune school children has proved brilliantly successful. In Auburn, New York, for example, the number of days of school attendance lost as a result of diphtheria was 22,438 in 1921–22

and only 1189 in 1922–23 after a vigorous Schick testing and toxin-antitoxin campaign. It was estimated that the value of the educational time thus salvaged was over $10,000.

The best of all methods of fighting diphtheria is to go back to a period long before the beginning of school life. Four-fifths of all deaths from diphtheria occur in children under five years of age so that we can not hope to accomplish very much without securing the toxin-antitoxin treatment of children of the "runabout" age. Since children in the second year are rarely immune against diphtheria it is a waste of time in this case to use the Schick test. What we should do is to immunize all children about the time of their first birthday with the toxin-antitoxin mixture; and just so far as this is done will diphtheria cease to take its toll of over 12,000 lives a year in the United States.

The Past and the Future

We have now reviewed in general outline the chief problems involved in the control of the germ diseases and the weapons which are available for the conflict against our microbic foes. It remains only to consider the ground which has been already gained in the war against disease and the promise of further victories in the future.

The great plagues and pestilences which killed our forefathers by the thousands in the Middle Ages have been practically banished from the world. In civilized countries, typhus fever and bubonic plague and Asiatic cholera have become rare medical curiosities. Even in the tropics yellow fever has been eliminated from all but a few isolated regions, and malaria and hookworm disease can be brought under control wherever the funds and the personnel are

available for the conduct of the specific measures indicated for their eradication.

Recent progress in the control of the more familiar infections which affect our own American communities is clearly indicated by the table below, which indicates the change in the death rate from certain groups of diseases in the United States Registration Area during the past twenty years.

	Deaths per 1,000 population		Reduction	Per cent reduction
	1900	1920		
Tuberculosis, diphtheria, typhoid fever, and diarrhea..	4.1	1.9	2.2	54
Other communicable diseases (Including particularly pneumonia and influenza)..	3.3	2.7	0.6	18
All other diseases.....	10.1	8.4	1.7	17
Total	17.5	13.0	4.5	26

In the case of four communicable diseases, tuberculosis, diphtheria, typhoid fever, and diarrhea, there has been effected a reduction of over 50 per cent. in the death rate during a period of two decades. The decrease of more than 2 per 1,000 in the case of this group of diseases means that every year two lives are saved for every thousand persons in the population or a saving of 200,000 lives in the United States each year. Here is a triumph for the forces of public health of which the generals of any victorious army might well feel proud. As the writer has elsewhere pointed out,[1] "If we had but the gift of second sight to transmute abstract figures into flesh and blood, so that as we walk along the street we could say, 'That man would be dead of typhoid fever,' 'That woman would have succumbed to tuberculosis,' 'That rosy infant would be in its coffin,' then only should we

[1] Winslow, C.-E. A. "The Evolution and Significance of the Modern Public Health Campaign." Yale University Press, New Haven, 1923.

have a faint conception of the meaning of the silent victories of public health. For such achievements we may thank God and take courage for the future, bearing on our banners that eternal phrase of Cicero: 'In no single thing do men approach the Gods more nearly than in the giving of safety to mankind.' "

The possibilities of the future are, however, quite as brilliant as those of the past. Half of the mortality from tuberculosis, typhoid fever, diphtheria, and diarrhea still remains to be eradicated. The other communicable diseases have yet to be effectively controlled; and there are vast possibilities of prevention among the diseases not directly due to the invasion of a hostile microbe.

Dr. Dublin of the Metropolitan Life Insurance Company has recently pointed out that in the State of Massachusetts (for which the longest series of records are available) the average age at which men die has increased from less than 40 years in 1855 to more than 55 years in 1920, an addition of fifteen years to the span of human life; and Dr. Dublin estimates that by the application of well-proven methods the average age of our American population could be increased to nearly 65 years, adding ten years more to the figure now attained.

Such are the past achievements and such the future possibilities of the public health campaign. The rate of its progress will depend only upon the financial and moral support which is given, on the one hand to the investigators who are constantly placing new weapons in our hands, and on the other to the administrative health officials who are directing the actual use of those weapons. If we can realize that this war against disease is a very grim reality, costing our country hundreds of thousands of lives in the course of every year, and mobilize our forces with

the same vigor we should display against a human foe, the victory will be assured, and we shall make rapid progress toward that happy condition foreseen by Pasteur in which the menace of microbic disease shall be lifted from the lives of men.

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